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PROTECTION AGAINST ELECTROMAGNETIC RADIATION WITH TEXTILE MATERIAL

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ABSTRACT

Today textiles are no more limited for wearing purpose only. The technological developments in recent years have developed technical textiles material, which can be used in various industries like automobile, advertising, agriculture, civil constructions, environmental protection, chemical, electronic, geo-textile, industrial coverings, medicals, printing, space, etc. This paper highlights the various textile material, their properties, manufacturing and application with special emphasis on role of textile material as an electromagnetic and electrostatic discharge protective device.

KEYWORDS: Technical Textile, Conductive Fabric, Electromagnetic and Electrostatic Discharge Protection

INTRODUCTION

When human life began on the earth, food and shelter were the two important necessities. Immediately thereafter, however, came clothing. From birth to death, we require textile. Textile industry plays a very important role in the country's economy. It is the largest economic activity after agriculture and providing direct and indirect employment to many people. Manufacture of Textiles is one of the oldest and largest industries of all.

"Textile" has traditionally meant, "a woven fabric". The term comes from the Latin word *texere*, meaning *to weave*. A textile is a cloth, which is either woven by hand or machine [1]. A type of material composed of natural or synthetic fibers.

TYPES OF TEXTILE MATERIAL

Basically there are only three types of textile material namely, Fibre, Yarn and Fabric as shown in the figure 1

Figure 1: Types of Textile Material [2, 3, 4]

Fibre

Fibre is the base of textile industry. There are end numbers of fibres available today. They are classified into two main category namely, natural fibres and synthetic fibres. Natural fibres are derived from sources in nature such as wool

and silk from animal, and cotton, jute from plants. Natural fibres are having limited length hence, they are known as staple fibre.

Synthetic fibres are made of polymers. Polymers can be classified in different ways such as thermoset and thermoplastic. By using different polymer types and fiber manufacturing conditions, certain properties can be programmed into the fibre. Crystallinity and molecular weight are among the typical characteristics that influence fibre properties.

Synthetic fibres can be produced in the long continuous length known as a filaments or be chopped into shorter lengths to make it staple fibre for blending with natural fibre. Synthetic fibres can be of mono or multi filaments. Filaments provide a smooth surface and high strength. Synthetic fibres can be made with different diameters, cross-sectional shapes and a combination of different polymeric materials like hybrid or bi-component fibers. Polyester, nylon, acrylic, polyethylene, polypropylene, glass, carbon etc. are the examples of synthetic fibres. Figure 2 shows staple and filament fibre.

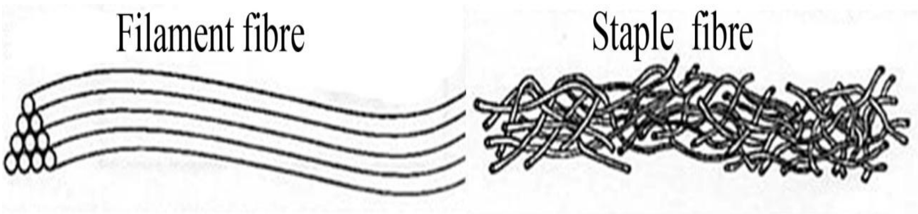

Figure 2: Staple and Filament Fibre [5]

Yarn

Fibres are converted into yarn by spinning process. A yarn can consist of monofilament, multifilament fibre, Staple fibres (natural and synthetic). Depending upon the type of fibre, there are different types of spinning processes like ring, rotor, friction, air-jet which provide the different yam structures and hence properties.

Fabric

Yarns are converted into fabric by various processes like weaving, knitting, braiding, needle felting, bonding, tufting, laying and knotting. The resulting fabric structure can be ribbons, felts, laid webs, woven fabrics, knitted fabrics, scrims, hells, cord fabrics, mats, nets, nonwovens, hoses narrow fabrics, ropes, screens, tapes, cables, carpets, wadding and cords. A fabric structure can consist of a single layer or multi layers. Each layer can be made of one or more types of fibers or yarns. Dyes, films, auxiliaries, impregnating agents, adhesives, plastics and other chemicals can be added to these textile products to obtain specific properties. Several chemical, physical and mechanical methods may be involved during the process such as coating, extrusion, dyeing, filling, impregnation, calendaring, backing, adhesive bonding, lamination, metallization, stitching, perforation, embossing, pre-pregging, pressing, punching, molding, stretching, vulcanization and cutting. Figure 3 shows the arrangement of yarns/fibres in the fabric produced by different fabric manufacturing process.

Figure 3: Different Types of Fabric Structure [6]

TECHNICAL TEXTILE

Today textiles are no more limited for wearing purpose only, their technical performance and functional properties mean much more than their aesthetic or decorative attributes. This has led to the emergence of a new term "Technical Textiles". Application of textile material was limited on earlier days. The technological developments in recent years have developed technical textiles material, which can be used in various industries like automobile, advertising, agriculture, civil constructions, environmental protection, chemical, electronic, geo-textile, industrial coverings, medicals, printing, space, etc. In many cases it has been replacing the conventional materials with low cost, high efficiency materials along with many other features [7].

History

Although the beginning of industrial textiles may be as old as traditional textiles dating back to several thousand years ago. The history of modern industrial textiles probably began with the canvas cloth used to sail ships from the old world to the new across the ocean. Later, hemp canvas was used on covered wagons to protect families and their possessions across the land. Fabrics were used in early cars as "rag-tops" to keep out the weather and as seat cushions for passenger comfort.

"Industrial textiles are specially designed and engineered structures that are used in products, processes or services of mostly non-textile industries" [8].

According to this definition, an industrial textile product can be used in three different ways

- An industrial textile can be a component part of another product and directly contribute to the strength, performance and other properties of the product, e.g. tire cord fabric in tires.
- An industrial textile can be used as a tool in a process to manufacture another product, e.g., filtration textiles in food production, paper machine clothing in paper manufacturing.
- An industrial product can be used alone to perform one or several specific functions, e.g., coated fabrics to cover stadiums.

The global technical textiles market is estimated at $100 million and anticipated to grow at the rate of 3.5 per cent by 2010. India's global share is expected to increase to 9 per cent by 2010, a report of the working group on chemicals and petrochemicals said [9].

With the growing dominance of Technical Textiles, Techtextiles Messe Frankfurt GmbH has classified technical textiles into these 12 groups from the application point namely, Agrotech, Buildtech, Clothtech, Geotech, Hometech, Indutech, Medtech, Mobitech, Oeakotech, Packtech, Protech, and Sporttech. Within each of these headings are literally hundreds of products and applications [10].

There are several differences between technical and traditional textiles that make technical textiles unique.

- **Application Areas and End Users of Technical Textiles**

Traditional textiles are used mainly for clothing and home furnishing. A traditional textile product such as a garment is purchased and used by the consumer. On the other hand, most of the time the purchaser of a technical fabric does not use it for himself directly. Therefore the direct user of technical textiles is usually not the individual consumer.

There is hardly any industry or human activity that does not involve the use of technical textiles in one way or another. Technical textiles are usually used in non-textile industries. Advertising, Agriculture, Automotive, Horticulture Pharmaceuticals are some of the users of technical textiles Almost every, modern non-textile industry uses technical textiles.

- **Performance Requirements**

Depending on the application areas, industrial textiles are designed to perform for heavy duty and demanding applications. Failure of an apparel textile during use may cause some embarrassment for the user at worst. For example, failure of an air bag in a car accident or an astronaut's suit during a spacewalk may be fatal.

Protective Texile (Protech)

In case of protective textiles, the industrial need is to offer the protection from extreme heat and cold, harmful chemicals, gases, bacterial environment, radiation and ballistic protection etc. [11]. For electrostatic discharge protection, the newly developed Gore-Tex "antistatic outerwear" assumes a number of protective functions at the same time: antistatic properties and protection against weather, heat and fire. The PTFE membrane positioned between outer material and lining contains nano-carbon particles which form a conductive grid structure and which allows electrical charges to discharge [12].

ELECTROMAGNETIC PROTECTION

The growth of the electronic industry and the widespread use of electronic equipment in communications, computations, automations, biomedicine, space, and other purposes have led to many electromagnetic interference (EMI) problems as systems operate in close proximity. Table 1 shows the radiation level of different electronic devices. Increased awareness of EMI has led to the formulation of new regulations around the globe for the manufacturers of electrical and electronic equipment to comply with the electromagnetic compatibility requirements [13].

Table 1: Frequency of Different Electronic Devices

Electronic Devices	Frequency (MHz)
Garage door openers, alarm systems	Around 40
Cordless phones	40 to 50
Baby monitors	49
Radio controlled air planes	Around 72
Radio controlled cars	Around 75
Wildlife tracking collars	215 to 220
MIR space station	145 to 437
Cell phones	824 to 849
Cordless phones	Around 900
Air traffic control radar	960 to 1,215
Global Positioning System	1,227 and 1,575
Deep space radio communications	2,290 MHz to 300

Electromagnetic Interference (EMI)

Electromagnetic wave consists of an electrical component and magnetic component perpendicular to each other and propagates at right angles to the plane. The waves are produced by the motion of electrically charged particles. These waves are also called “electromagnetic radiation” because they radiate from the electrically charged particles. They travel through empty space as well as through air and other substances.

Electromagnetic interference is disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct or otherwise degrade or limit the effective performance of the circuit. These effects can range from a simple degradation of data to a total loss of data. The source may be any object, artificial or natural, that carries rapidly changing electrical currents, such as an electrical circuit [13].

Effects on Human Body

If an electromagnetic wave gets into an organism, it vibrates molecules to give out heat. In the same way, when an electromagnetic wave enters the human body, it will obstruct a cell's regeneration of DNA and RNA. Furthermore, it brings abnormal chemical activities to produce cancer cells, and increases the possibility of cancer across all the body organs, brain tumor, breast cancer, leukemia, heart attack, some skin diseases, depression, etc. Injuries by electromagnetic waves to the human body are the top priority of professionals and scholars, and we are most concerned with solving this problem.

The simplest and most effective way to prevent electromagnetic radiation hazards is to stay away from the radiation source. However, as this is not always possible, different protection methods have been developed. One of the main methods used in protection from electromagnetic radiation is ''shielding''. Shielding can be described as reducing the electromagnetic field in a space by blocking the field with barriers made of conductive or magnetic materials. Electromagnetic shielding materials are usually used to reduce the intensity of electromagnetic fields.

To protect against EMI, circuits are sometimes shielded in metal enclosures or metal coated plastic. Shields made as metal sheets or foil, and metal mesh are characterized by a good EM field shielding effectiveness coefficient. However they are characterized by low resistance to environmental impact. Their fundamental disadvantage is weight. They are primarily used in low frequency electromagnetic field shielding. EMI filters are built into the equipment circuitry. But the circuit is not flexible, costly and it is set in Instrument, metals are heavy etc are the drawbacks associated with old method. But textile material is flexible, less cost, more production, light weight, washable and withstand with climatic condition and have a relatively lower cost.

Shielding Effectiveness

Shielding can be specified in the terms of reduction in magnetic (and electric) field or plane-wave strength caused by shielding. The effectiveness of a shield and its resulting EMI attenuation are based on the frequency, the distance of the shield from the source, the thickness of the shield, and the shield material. Shielding effectiveness is normally expressed in decibels (dB) as a function of the logarithm of the ratio of the incident and exit electric (E), magnetic (H), or plane-wave field intensities SE (dB) = 20 log (E0/E1), SE (dB) = 20 log (H0/H1), and SE (dB) = 20 log (F0/F1) respectively.

With any kind of electromagnetic interference, there are three mechanisms contributing to the effectiveness of a shield. Part of the incident radiation is reflected from the front surface of the shield, part is absorbed within the shield material, and part is reflected from the shield rear surface to the front where it can aid or hinder the effectiveness of the shield depending on its phase relationship with the incident wave. Therefore, the total shielding effectiveness of a shielding material (SE) equals the sum of the absorption factor (A), the reflection factor (R), and the correction factor to account for multiple reflections in thin shields: $SE= R+A+B$

All the terms in equation are expressed in dB. The multiple reflection factor B can be neglected if the absorption loss A is greater than 10dB. In practical calculation, B can be neglected for electric fields and plane waves [14].

EMI SHIELDING WITH TEXTILE MATERIAL

Except metallic fibres, E-glass and carbon fibre, other textile materials are insulator. To use textile material as an electromagnetic shielding device, it should be electrically conductive. So first textile materials are made electrically conductive by various methods and then it is used as a shielding material. Conductive fibers and yarns have drawn considerable attention during the last decade.

Methods of Producing Conductive Textile

Fibre, Yarn and Fabric are the three basic textile material, so textile can be made electrically conductive at fibre, yarn or fabric stage.

Methods of Imparting Electrical Properties at Fibre Stage

- Draw blending of metal and textile slivers
- Treatment with metallic salts
- Galvanic coating
- Coating fibers with conductive particles suspended in a resin
- Vacuum spraying

Methods of Imparting Electrical Properties at Yarn Stage

Methods of producing conductive yarns can be summarized as follows:

- Adding carbon or metals in different forms such as wires, fibres or particles (e.g. core spun, blends)
- Using inherently conductive polymers
- Coating with conductive substances

By utilizing the conductive yarns in the fabric structures, various functionalities may be attributed to the fabrics. Enhancing both the properties of textile structures and the function of conductivity, conductive textiles have important applications not only in medical and military fields, but also in the fields of fashion, architecture and design for their aesthetic appeal. Therefore textiles with conductivity function are used in many technical applications such as protection of people and electronic devices from electromagnetic interference (EMI) and electrostatic discharge, heating, wearable electronics, data storage and transmission, sensors and actuators.

Conductive yarns are either pure metal yarns or composites of metals and non-conductive textile materials that help improve mechanical properties As a thread becomes more conductive and takes a bigger portion of the conductive component, it loses the typical textile properties such as flexibility or drapability. Metal-wrapped yarn is a composite of metal and yarn. A conductive yarn mainly consists of a strand of non-conductive yarn wrapped with one or more metal wires. For metal-filled yarns, a fine metal wire serves as a core covered by non-conductive fibers. Textile coverings can protect a core metal wire, helping it withstand physical stresses and providing electrical insulation. Metal yarn does not take a core-sheath structure. Metal fibers that are very finely drawn replace one strand or entire strands of the yarn. Metal fibers are prepared in forms of either filaments or staple fibers and processed as a conventional yarn.

Methods of Imparting Electrical Properties at Fabric Stage

Fabric can be made conductive by (i) laminating conductive layers onto the fabric surface, such as electro less plating, evaporative deposition, conventional coating (direct coating) and coating fabric with conductive polymer, zinc arc sprays, ionic plating, vacuum metalized sputtering and metal foil binding. (ii) Incorporating conductive fibers or yarn in fabric because the fibers are closely spaced, conductive path can be easily established. The above methods can be categorized under two headings, such as surface treatments and fillers. Surface treatments are often time consuming, labor intensive, and costly. Conductive fillers in the form of particulates, filament, and woven fabrics are increasingly being used for shielding electromagnetic radiations. Attempts by researchers using woven fabric indicate that the shielding effectiveness of the fabrics depends on the conductive filler content [15].

METHODS OF TESTING EMSE

There are different standard test methods for measuring electromagnetic shielding effectiveness. ASTM D-4935 test method is used for measuring electromagnetic shielding effectiveness of planer material like fabric, other methods are listed below:

- MIL-STD 285 AND IEEE STD-299
- NSA 65-6 AND NSA 94-106
- MIL-STD 461E
- ANSI\SCTE 48-3
- IEC STANDARDS
- ITU-T RECOMMENDATIONS

ASTM D-4935

In this method, the test adapter is constructed using a section of 50Ω coaxial aerial, having an external-to-internal diameter ratio of 76 to 33mm. The shielding effectiveness measurements are carried out for frequencies ranging from 30MHz to 1.5GHz. In practice, measurements starting from about 1MHz would be possible, although certain limitations arise at lower frequencies because of the capacitive coupling operation and the limited dynamic range of the measurement devices, or to be more precise, that of the network analyzer used for these measurements. The measurement device may consist of a network analyzer, which is capable of measuring insertion loss and return loss. The shielding effectiveness is determined by comparing the difference in attenuation of a reference sample to the test sample, taking into account the insertion and return losses. The measurement procedure consists of two stages; in the first stage, a reference sample is placed in the test adapter to compensate for the coupling capacitance. Figure 4 shows the test setup for measurement of electromagnetic shielding effectiveness of electrically conductive fabric [16].

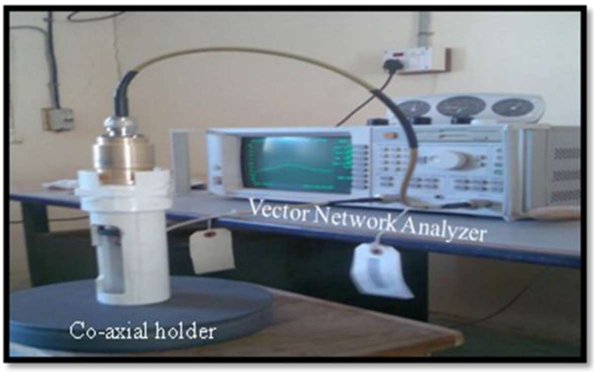

Figure 4: Test Setup for Measurement of EMSE as Per ASTM D-4935

Criteria for Selection of Materials and Fabrication Technologies for Shielding

Materials used in the technique of electromagnetic field shielding must meet following conditions: have a suitably high coefficient of the shielding effectiveness [17],

- Be resistant to mechanical impact and easy to handle,
- Be resistant to harmful influence of external environment (oxidation, corrosion),
- Durable,
- Homogenous,
- Easy to form the shield,
- Low costs of production.

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